EXPANDING NATURAL GAS CROSS-BORDER FLOWS IN EUROPE THROUGH THE OPTIMAL USE OF THE PIPELINE GRID: A STYLIZED MODEL COMPARISON

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Overview

The energy crisis in Europe in the wake of the Russian war in Ukraine has once again highlighted the importance of trans-boundary grid infrastructure for flexibility and supply security. Thus, within several months, the large-scale disruption of natural gas flows from Russia to Europe had to be mitigated by pipeline flows from different direction within Europe, and liquefied natural gas (LNG) imports from overseas. However, the European gas grid has also shown signs of congestion, which have limited the flexibility of exchange and reduced supply security.

One instrument that can be applied to relieve the situation is to optimize the bilateral flows in cross-border pipelines. At present, the optimal use of the pipelines is constrained by negotiated caps on the flows. Concretely, the maximal flows between country A and country B are differentiated, so that the maximum pipeline flow in one direction, say from A to B ($f_{max\ A\ to\ B}$) is different from the maximal flow in the inverse direction, i.e. B to A ($f_{max\ B\ to\ A}$). This is the case, for example, for flows between Germany and the Czech Republic ($f_{max\ G\ to\ CZ}$ = 95,9 billion cubic meter (bcm), whereas $f_{max\ CZ\ to\ G}$ = 38,5 bcm), between France and Belgium ($f_{max\ F\ to\ B}$ = 21,3 bcm, $f_{max\ B\ to\ F}$ = 30,3 bcm), or between the Netherlands and Germany ($f_{max\ NL\ to\ G}$ = 65,0 bcm, $f_{max\ G\ to\ NL}$ = 32,5 bcm). The capacities are negotiated between the countries and their respective network operators. From an energy economic perspective, the optimal use of these capacities would suggest symmetry, assuming that the technical conditions for bi-lateral flows are given, or can be established at low costs.

Methods

We calculate the effect of an optimal utilization of the existing natural gas grid in two models, the "Global Gas Model" and the Global Energy System Model ("GENeSYS-MOD"), and then proceed with a model comparison between the two.

- The Global Gas Model (GGM) is a multi-period equilibrium model for analyzing the world natural gas market along the value chain from production wells to final consumers; market agents include producers, traders, transmission system (TSO) and storage operators (SSO). The TSO manages the pipeline network as well as the LNG liquefaction and regasification terminals. The GGM has a detailed representation of the European natural gas pipelines, and therefore can be used to estimate the potential effects of an optimal use of capacity (Figure). The model has been previously used to simulate European and global scenarios, such as (Holz et al. 2017; Egging, Holz, and Czempinski 2021).
- GENeSYS-MOD, the Global Energy System Model, is an open-source energy system modeling framework. The model endogenously determines cost optimal investment paths into conventional and renewable energy generation, different storage technologies, and some infrastructure investments in five-year steps until 2050 (Figure). GENeSYS-MOD has also been applied to issues of the European energy market restructuring, including natural gas, such as (Hainsch et al. 2018; Auer et al. 2020; Hainsch et al. 2021).

The theory of optimal pipeline utilization has been discussed in a variety of papers and studies, such as (Cremer, Gasmi, and Laffont 2003). It corresponds to theories on "nodal pricing" that has been applied in theory and in practice in the electricity sector (Hogan 1992; Stoft 2002, Chapter 4; Neuhoff et al. 2013) and, more generally, optimal use of infrastructure.

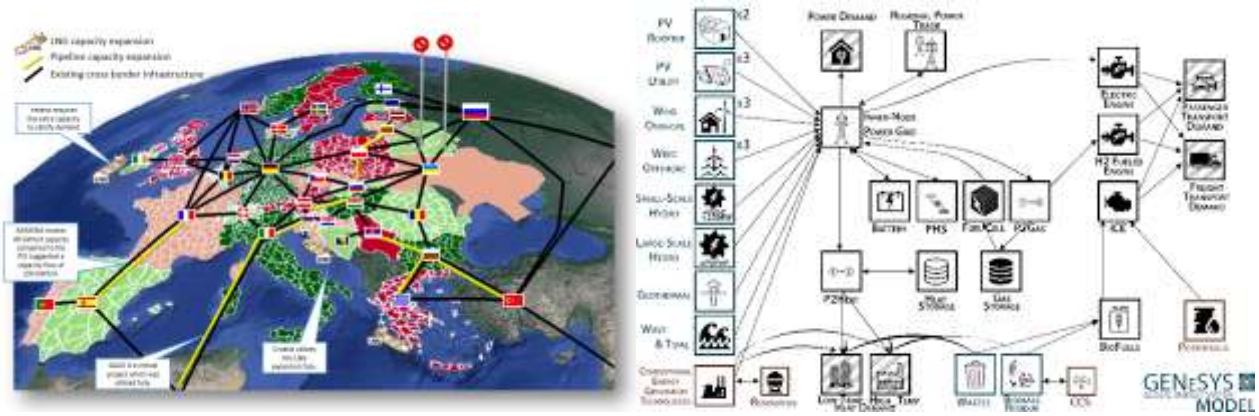

Figure 1: European representation of the Global Gas Model (GGM) and representation of the Global Energy System Model (GENeSYS-MOD)

Sources: https://www.ntnu.edu/iot/energy/energy-models-hub/ggm, https://openentrance.eu/2021/04/27/genesys-mod-tu-berlin/ [last access 2023-03-16]

Expected Results

At this point, test runs are carried out with both models. For the paper, both models will perform baseline runs for 2020 and 2025, with and without capacity restrictions on cross-border flows. This will provide an indication of the importance of the optimal use of capacity in these years, in terms of flows and prices. In addition, a scenario run for the case of the 2022 energy crisis including Russian supply disruption is carried out: How much would an optimal use of natural gas pipeline grids have contributed to relieving the energy crisis in 2022 (Kotek et al. 2023)? The paper also contains a discussion of the institutional aspects of pipeline regulation as well as a discussion of investment requirements in the EU pipeline grid.

Conclusions

The efficient use of pipeline infrastructure may be an important lever for supply security and flexibility in Europe and beyond. This model comparison exercise provides some insights into the importance of the issue, and potential changes in flows once the constraints are relieved.

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